Comparative Study of Performance and Emission Characteristics of a Diesel Engine Fueled by Castor and Jatropha Methyl Ester with the Help of T Test

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Abstract
Biofuels are playing important role in recent decades as substitutes for petro diesel. Biodiesel derived from vegetable oils are found to give comparable performance and emission characteristics. In this paper a comparative study has been done between two fuels combinations i.e. jatropha and castor. The biodiesel was prepared from neat oils and blends of biodiesel (up till 20%) were prepared with diesel. Produced blends were tested for their use as a substitute fuel for diesel in a single cylinder diesel engine. On the observed data for both the fuels, Student t statistical test was applied. The values for fuel consumption calculated for t were 0.088 for jatropha oil methyl ester (JOME) and 0.44 for castor oil methyl ester (COME) blends. Similarly for emission characteristics the values for CO_2, CO, NOx calculated for t were 2.94, -4.781, 2.83 for COME and 5.48, -2.91 and 4.24 for JOME respectively. The values concluded that there is no effect of fuel type on fuel consumption up till 20 percent biodiesel blended fuel with respect to performance and emission characteristics.

Keywords: *Jatropha oil methyl ester, Castor oil methyl ester, Brake thermal efficiency, Fuel consumption, Student Ttest.*

1. INTRODUCTION

Rudolf Diesel, the inventor of diesel engine at the world exhibition in Paris presented the concept of using the biofuels in diesel engine. R&D activities in this area were not carried out because of the abundant supply of petrodiesel at that time. Only recently the importance of biofuels was realized when it was noticed that these resources are depleting fast and also they are polluting the environment (Agarwal and Das (2000)). Recently many serious efforts have been made by several researchers to use different sources of energy as fuel in existing diesel engines. Higher viscosity of neat vegetable oil makes them incompetent fuel to be used directly in the diesel engine. Injectors of the engines get choked after few hours if they are directly run on neat vegetable oil (Agarwal (2007)). Viscosity of neat oils can be reduced by blending it with diesel or by the process of transesterification, which produces biodiesel. Worldwide transesterification has been accepted as an effective means of biodiesel production and viscosity reduction of vegetable oil. Transesterification process is influenced by temperatures, catalyst type, concentration ratio of alcohol to fuel and stirring speed rate (Ma and Hanna (1999)). The important compositional difference between biodiesel and the diesel fuel is concerned with oxygen content. Biodiesel contains 10–12% oxygen on weight basis and this lowers the energy content. The lower energy content causes reductions in engine torque and power, (Avinash Kumar Agarwal (2007)) and (Sahoo et al.(2007)). It has been reported that biodiesel containing oxygen reduces exhaust emissions such as HC and CO mainly because of complete combustion. Since biodiesel contains little sulphur compared to the diesel fuel, a significant reduction in SO2 emission was observed by N. Usta (2005).

The price of edible vegetable oils is higher than that of the diesel fuel. Therefore, instead of using such oils, use of waste vegetable oils (Sudhir et al. (2007)) and (Yu et al. (2002)) and non-edible crude vegetable oils (Pramanik (2003)), and (Bari (2002)) have been considered as potential alternative fuels. In this regard research on different oils carried out on such as jatropha oil (Tiwari et al. (2007)), castor oil (Chakrabarti and Ali (2009)), polanga seed oil (P.K. Sahoo et al. .(2007)) , karanja oil (Naik et al. (2008)), palm oil (Bari et al. (2002)), tobacco oil (Usta (2005)) , coffee oil (Oliveira et al. (2007)), mahua oil (Ghadge and Raheman (2005)), rubberseed oil (Ramadhas et al. (2005)) microalgae oil (Chisti (2007)), rice bran oil (Sinha et al. (2008)), beef tallow (Nelson and Schrock (2006)),waste cooking oil (Sudhir et al..(2007)), linseed oil (Agarwal and Das (2000)), Soyabeen oil (Chiu et al. (2004)). Also the energetic feasibility of Jatropha biodiesl in terms of energy ratio has been very well explained by Vashist and Ahmad (2009).

To compensate for the shortages of diesel fuel, the adaptation of a selected alternative fuel to suit the diesel engine is considered more economically attractive in the short-term than engine modification to suit the fuel. For this purpose, an alternative liquid fuel that will blend readily with diesel fuel is required. Such an alternative fuel should lend itself to local production in adequate and economic quantities. There should be little modifications to the existing engine. Engine performance and durability should not be affected significantly.

In the present investigation, two non edible oils are taken i.e castor seed oil and jatropha seed oil, biodiesel from both the oils were produced and then studied on the compression ignition engine. Statistical t test was applied on the obtained data for knowing significant effect with the addition of biodiesel with diesel on the engine performance and emission characteristics.

2. ESTERIFICATION OF CASTOR AND JATROPHA SEED OIL

Castor and jatropha oil was converted into biodiesel by two and three stage transesterification reaction respectively.

$$RCOOR' + R''OH \leftrightarrow RCOOR'' + R'OH \qquad (1)$$

Important properties of transesterified oils were evaluated for comparison with diesel available in the local market. These are given in Table 1.

The prepared jatropha oil methyl ester (JOME) and castor oil methyl ester (COME) was mixed with diesel in four different proportions i.e. 5%, 10%, 15% and 20% to prepare its blends i.e. JOME5, JOME10, JOME15, JOME20, COME5, COME10, COME15 and COME20.

3. EXPERIMENTAL METHODOLOGY

A Four-stroke single cylinder diesel engine (Plate 1) with mechanical rope brake loading (Plate 2) was used for this study. It is a single cylinder, four stroke, vertical, water-cooled engine having a bore and stroke of 80 and 110 mm respectively. The compression ratio was 16.5 at rated speed of 1500 rpm. It has a provision of loading through rope brake dynamometer. The inlet valve opens at 4.5o before top dead center and closes at 35.5o after bottom dead center, the exhaust valve opens 35.5o before bottom dead center and closes 4.5o after top dead center. The engine specifications are shown in the table 2.

The engine was tested with pure diesel and prepared blends of jatropha and castor biodiesel at 100% loading at a speed of 1500 rpm only. The engine was started with standard diesel fuel and warmed up. The warm up period ends when cooling water temperature is stabilized. Fuel consumption, brake power, brake thermal efficiency, exhaust gas temperature were measured along with CO_2, CO and NOx emissions with different blends of jatropha and castor methyl ester.

Table 2. Engine specification

BHP	5
Speed	1500 RPM
Number of cylinders	ONE
Compression Ratio	16.5 : 1
Bore	80 mm
Stroke	110 mm
Orifice Diameter	20mm
Type of Ignition	Compression Ignition
Method of loading	Rope Brake
Method of Starting	Crank Start

Table 1. Chemical properties of jatropha and castor oil

Parameters	Jatropha oil	Castor oil	Jatropha biodiesel 100%	Castor biodiesel 100%	High speed diesel
Density at 25°C (kg/m^3)	960	950	875	905	810
Kinematic viscosity mm^2/sec	240	230	13	12.5	3.05
Flash point (°C)	340	305	140	115	53
Fire point (°C)	350	320	150	121	56

Plate 1. Single Cylinder Diesel Engine

Plate 2. Rope Drake Dynamometer

3. 1. Student's t Distribution

Student's t distribution has different shapes depending upon the size of the population. When the sample is quiet small the height of the t distribution is shorter than the normal distribution and the tails are wider. As n nears 30 the t distribution approaches the normal distribution in shape. When the population distribution is normal and standard deviation σ is unknown then the "t" statistic is defined as:

$$t = \frac{x - \mu}{\sigma / \sqrt{n}}$$

Follows the student's t-distribution with (n-1) d.f

Where x = sample mean

μ = hypothesized population mean

n = sample size

and σ is the standard deviation of the sample calculated by the formulae:

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

The null hypothesis to be tested is weather there is a significant difference between $\bar{x}$ and μ. If the calculated value of t exceeds the table value of t at a specified level of significance, the null hypothesis is rejected and the difference between $\bar{x}$ and μ is regarded significant. If the calculated value of t is less than the table value, the difference between $\bar{x}$ and μ is not considered to be significant. The test is based on n-1 degrees of freedom.

4. RESULTS AND DISCUSSION

4. 1. Fuel Consumption

Table 3 and figure 1 shows the effect of load on fuel consumption for the different JOME and COME

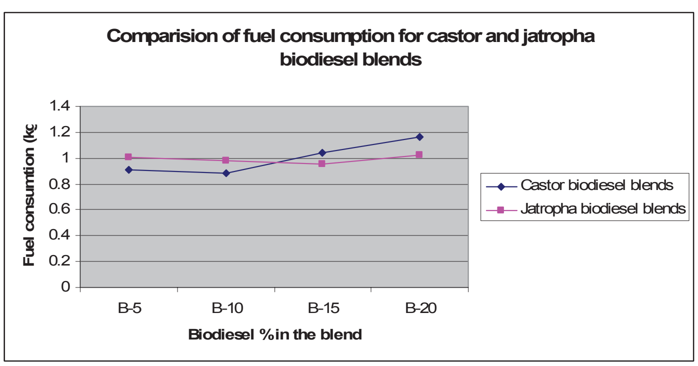

Fig. 1. Comparison of fuel consumption for castor and jatropha biodiesel blends

Table 3. Fuel consumption data

Fuel type	Diesel	JOME 5 / COME 5	JOME 10 / COME 10	JOME 15 / COME 15	JOME 20 / COME 20
Fuel consumption (Kg/Hr)	0.97	1.009 / 0.911	0.9792 / 0.88	0.951 / 1.04	1.02 / 1.166

blends. Applying the t test for the given below data by assuming the a null hypothesis that consumption of petrodiesel is not different from the consumption of blends of biodiesel.

Considering

$\mu = 0.97$ (consumption of diesel)

$t_{castor} = 0.44$

$t_{jatropha} = 0.088$

The table value of t for 3 degrees of freedom at 5% level of significance is 3.182. The computed value of t for castor is smaller than table value (hypotheses accepted) while for jatropha blends computed value of t is again smaller than table value (hypotheses accepted). From this conclusion can be drawn that consumption of petrodiesel is not different from the consumption of blends of biodiesel up till 20%.

4. 2. CO_2 Emission

High value of CO_2 is due to the presence of more carbon atoms as well as higher oxygen content in biodiesel fuel. Table 4 and figure 2 shows the effect CO_2 vol% variation at 100% load for various fuel blends.

Considering null hypotheses to be emission of CO_2 from petrodiesel is not different from the emission from blends of biodiesel.

We have

$\mu = 4.8$ (CO_2 emission from diesel)

$t_{castor} = 2.94$

$t_{jatropha} = 5.48$

The table value of t for 3 degrees of freedom at 5% level of significance is 3.182. The computed value of t for castor is smaller than table value (hypotheses

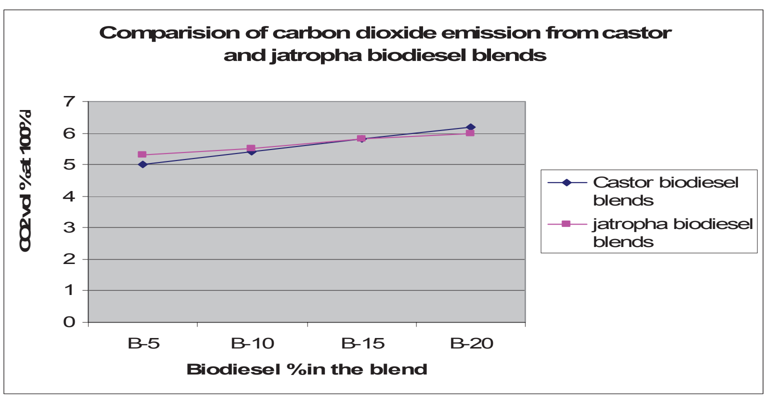

Fig. 2. Comparison of CO_2 emission from castor and jatropha biodiesel blends

Table 4. Vol% of CO_2 in exhaust for different blends

Fuel type	CO_2 vol% Load (100%) for Castor biodiesel blends	CO_2 vol% Load (100%) for Jatropha biodiesel blends
Diesel	4.8	4.8
B5	5	5.3
B10	5.4	5.5
B15	5.8	5.8
B20	6.2	6

accepted) while for jatropha blends computed value of t is greater than table value (hypotheses rejected).

4. 3. CO Emission

CO emission decreases for the blended fuel at full load as is seen from the figure 3 and table 5. This phenomenon can be explained by the enrichment of oxygen owing to biodiesel addition. The increasing proportion of oxygen in the blend will promote further oxidation of CO during the engine exhaust. This is seen clearly from the table 4 and figure 2 which show the increase in CO_2 with the increase of biodiesel in the blend.

Assumed null hypotheses is emission of CO from petrodiesel is not different from the emission from blends of biodiesel.

Considering

μ = 2.56 (CO emission from diesel)

t_{castor} = - 4.78

$t_{jatropha}$ = - 2.91

The table value of t for 3 degrees of freedom at 5% level of significance is $\pm$3.182. the computed value of t for castor is greater table value (hypotheses rejected) while for jatropha blends computed value of t is smaller than table value (hypotheses accepted).

4. 4. NOx Emission

The NOx emission of different fuel types is shown in the table 6 and figure 4. The NOx emission depends on the engine type, engine operating conditions and fuel properties. It can be seen from the figure 4 that raising the biodiesel from 5 to 20 percent, also increases the NOx level from 107 to 118 ppm for castor biodiesel at 100% load. It may be noted that lean fuel with high cylinder temperature may generate higher NOx emission levels. It may be due to the higher heat release rate at the premix or slow combustion phase. Other reasons for more NOx formation may be high temperature in the cylinder, mixture remains at high temperature for more duration or increased oxygen concentration in the mixture. All these factors may have played a dominant role in NOx formation.

Assumed null hypotheses is emission of NOx from petrodiesel is not different from the emission from

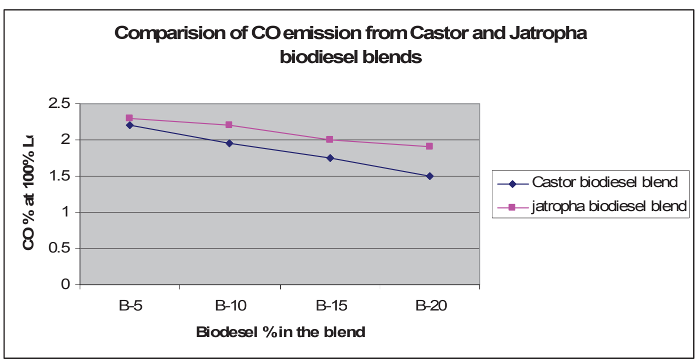

Fig. 3. Comparison of CO emission from castor and jatropha biodiesel blends

Table 5. CO Emission for biodiesel blends

Fuel type	CO Emission Vol % Load (100%) for castor biodiesel blends	CO Emission Vol % Load (100%) for jatropha biodiesel blends
Diesel	2.56	2.56
B5	2.2	2.3
B10	1.95	2.2
B15	1.75	2
B20	1.5	1.9

Table 4. Vol% of CO_2 in exhaust for different blends

Fuel type	NOx emission in ppm Load (100%) for castor biodiesel blends	NOx emission in ppm Load (100%) for jatropha biodiesel blends
Diesel	105	105
B5	107	117
B10	109	129
B15	115	136
B20	118	148

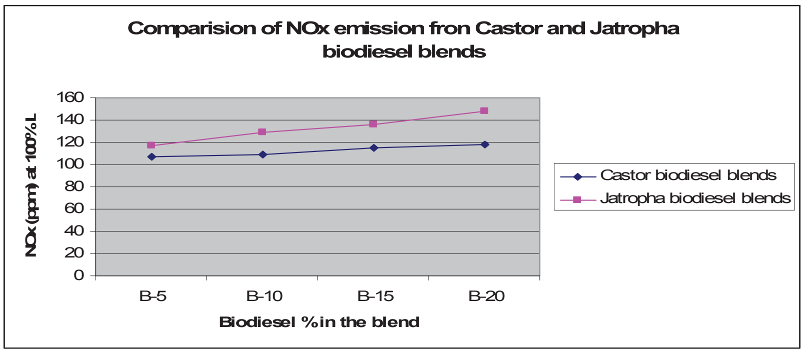

Fig. 4. Comparison of NOx emission from castor and jatropha biodiesel blends

blends of biodiesel.

Considering

μ = 105 (NOx emission from diesel)

t_{castor} = 2.83

$t_{jatropha}$ = 4.24

The table value of t for 3 degrees of freedom at 5% level of significance is 3.182. the computed value of t for castor is smaller than table value (hypotheses accepted) while for jatropha blends computed value of t is greater than table value (hypotheses rejected).

5. CONCLUSION

Biodiesel is a clean burning fuel that is renewable and biodegradable. Two non edible oils source plants selected for the performance tests do not compete with the edible crops and can be grown on the uncultivable waste lands. Also in the event of short supply of the single source a comparable source is available at the rural level itself. Castor oil methyl ester and jatropha oil methyl ester blends showed performance characteristics close to diesel, therefore COME and JOME blends can be used in CI engines in rural area for meeting energy requirement in various agricultural operations such as irrigation, threshing, etc. Statistically by the summarized t test table 7, it is has been proved that for the given range there is no significant effect of fuel type on fuel consumption as well as on emission.

Within this range of blend percentage engine develops better power when compared with power output with diesel. High power output is reported in many other studies it may be due to better lubricity

Table 7. Summarized result of t test

Fuel type	NOx emission in ppm Load (100%) for castor biodiesel blends	NOx emission in ppm Load (100%) for jatropha biodiesel blends
Diesel	105	105
B5	107	117
B10	109	129
B15	115	136
B20	118	148

which reduces friction loss and better combustion of blends. Statically the obtained parameters were checked with the help of the Students t test t which indicated that for the given range there is no significant effect of fuel type on fuel consumption.

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